ANKLE JOINT LOADING DURING THE DELIVERY STRIDE IN CRICKET MEDIUM- FAST BOWLING

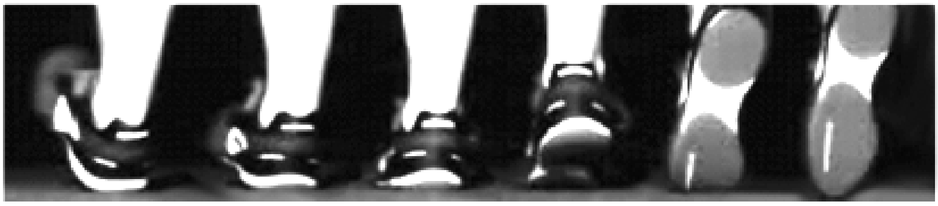
Kathleen Shorter, Neal Smith, and Mike Lauder
University of Chichester, Chichester, UK

To date, biomechanical research investigating the aetiology of cricket injuries has studied the kinetics and kinematics of associated movements in isolation. The aim of this study was to apply inverse dynamics to investigate ankle joint forces during the delivery stride using four Basler 200 Hz cameras synchronised to two Kistler 9581B force plates with Peak Motus 9.2. Although peak ankle joint moment in the sagittal plane was greater for the front foot (mean: 3.21 ± 1.71 Nm·Kg^{-1}) in relation to the back foot (mean: 1.70 ± 0.87 Nm·Kg^{-1}); average rate of joint loading was 246% greater in the frontal plane for the back foot (mean: 1.11 ± 0.82 Nm·Kg^{-1}·s^{-1}) compared to the front foot (mean: 0.45 ± 0.20 Nm·Kg^{-1}·s^{-1}). Findings would suggest that whilst the front foot is prone to acute injuries, the back foot may be more susceptible to overuse injuries such as lateral ankle instability.

KEY WORDS: kinematics, force, joint moment, injury

INTRODUCTION: Cricket injury epidemiology studies have established 11% of injuries afflicting fast bowlers involve the foot and ankle with no distinction made between the front and back foot (Orchard *et al.,* 2002). Smith (1999) reported a high incidence of posterior talar impingement afflicting elite South African bowlers, which was associated with rapid force application and ankle plantar flexion during front foot impact. Hurrion *et al.* (2000) established that impact forces during the delivery stride are in the region of 2.37 times body weight (BW) vertically and 0.94 BW horizontally for the back foot and 5.7 BW vertically and 3.5 BW horizontally during front foot impact, which may be modified by footwear (Shorter *et al.,* 2008). Whilst it is assumed that the front foot would be at greater risk of injury due to larger impact forces, contrasting foot movement during the delivery stride as depicted in Figure 1 would suggest that the nature and susceptibility of injuries may vary between the back and front foot.

Back Foot



Front Foot

Figure 1: Pictorial description of back and front foot contact from heel strike to toe-off during the delivery stride

Cricket studies investigating the aetiology of injuries have reported the kinematics and kinetics of the delivery stride in isolation. Whilst informative, the multi-factorial nature of injuries supports the need to investigate the causation of injuries in a similar manner. The susceptibility of a joint to injury is dependent on both the forces acting upon it, combined with the position of the joint. The aim of this study was to apply inverse dynamics as described by

Winter *et al.* (1990), to quantify the ankle joint forces experienced during the delivery stride to provide greater insight into the pathomechanics of associated ankle injuries.

METHODS: After gaining University ethical approval eight medium-fast amateur bowlers of mixed ability and technique (age: 22.38 ± 2.50 years, height: 1.80 ± 0.06 m, mass: 83.03 ± 16.10 Kg) were recruited and provided informed consent. All bowlers wore standardised footwear with which they had become habituated.

Testing was conducted indoors with adequate movement space to allow for a standard run-up. Smartspeed light gates (Fusion Sport, Queensland, Australia) were set two metres apart, two metres from the popping crease to monitor approach velocity prior to the delivery stride. Foot impact during the delivery stride was captured using two Kistler 9581B force plates (600 Hz) synchronised with four 200 Hz Basler digital cameras using Peak Motus 9.2 software. Lower limb kinematics during the delivery stride were reconstructed using the CAST technique (Cappozzo et al, 1995). For each limb eight retroflective markers: femoral epicondyle, tibial cluster comprised of three markers, lateral malleolus, posterior calcaneous, 2^{nd} metatarsal head and 5^{th} metatarsal head, were used to define the shank and foot segments with a marker subset used whilst bowling.

Prior to data collection, participants underwent a self-selected warm-up. Participants were required to bowl 10 successful balls for the foot under investigation. A successful ball was classified as one when full foot interaction with the force plate occurred whilst also complying with the laws of cricket as determined by the researcher.

All trials were digitised using Peak Motus 9.2 software, with kinematic data filtered using quintic spine processing. Kinematic and kinetic data were extrapolated to 200 Hz and exported into Visual3D for analysis. Foot contact for each foot was defined from the first instant vertical force exceeded 20 N, with toe off subsequently defined by the moment vertical force equated zero. Ground reaction force (GRF) data were normalised to participant body weight and analysed to determine peak force in both vertical and horizontal planes. Ankle joint kinetics of the back and front foot during the delivery stride were defined by peak and average joint moments in each of the cardinal planes and normalised to body weight. To further describe the forces acting on the ankle joint throughout foot contact, the average rate of joint loading in each plane was calculated by dividing the average rectified joint moment by the duration of foot contact.

RESULTS AND DISCUSSION: Similar to the findings of Hurrion *et al.* (2000), ground kinetics between the front and back foot during the delivery stride differed. Figure 2 depicts a representative combined back and front foot GRF trace during the delivery stride. Peak GRFs for the front foot (3.02 ± 0.87 BW vertically, 1.52 ± 0.48 BW horizontally) were greater in magnitude compared to the back foot (2.16 ± 1.43 BW vertically, 0.50 ± 1.12 BW horizontally). Disparity in peak force generation may partly be attributed to prolonged front foot contact (0.50 ± 0.18 s), which was 1.67 times longer in duration compared to the back foot (0.30 ± 0.05 s). Duration of foot contact during the delivery stride between feet has not been previously reported, however the role of the front foot to provide a stable base of support during ball release may necessitate prolonged foot contact.

Ankle joint moments for both the back and front foot during the delivery stride were found to closely reflect the typical movement pattern associated with pace bowling (refer to Figure 1). Figure 3 depicts a representative combined back and front foot moment-time trace where differences in joint kinetics were evident reflecting the different functional requirements of each foot.

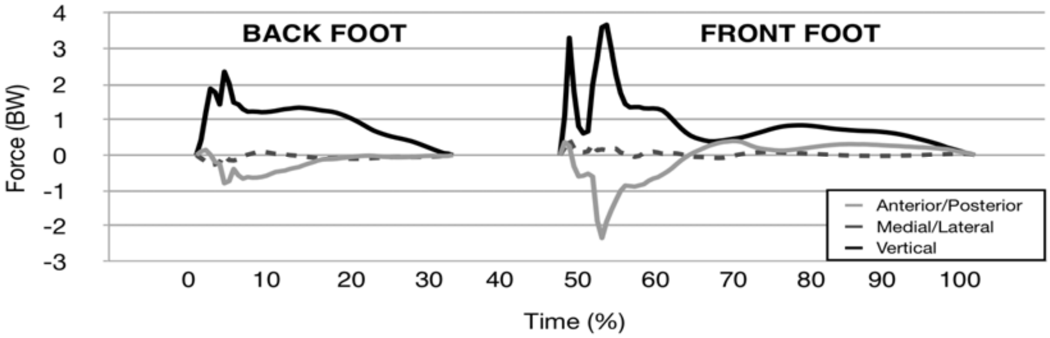


Figure 2: Representative combined back and front foot GRF trace during the delivery stride

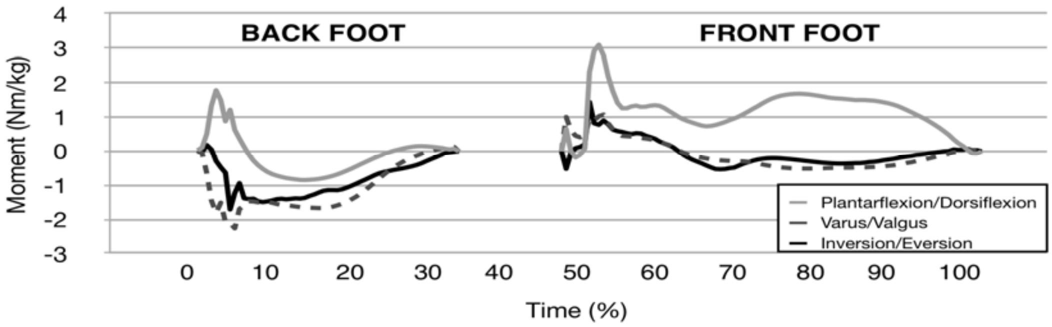


Figure 3: Representative combined back and front foot ankle joint moment trace during the delivery stride

Back foot contact was typified by a lateral forefoot strike corresponding with peak ankle joint moments. The peak eversion moment (mean: 0.96 ± 0.74 $Nm{\cdot}Kg^{-1}$) closely coincided with the peak plantarflexion moment (mean: 1.70 ± 0.87 $Nm{\cdot}Kg^{-1}$), in order to stabilise the foot through resisting ankle inversion. As foot contact progressed, sagittal plane torque decreased into dorsiflexion when the centre of pressure shifted towards the heel. Throughout foot contact a valgus moment (mean peak: 1.68 ± 1.11 $Nm{\cdot}Kg^{-1}$) was evident due to the perpendicular position of the foot in relation to the body, combined with the upper body pivoting around the lower limb in preparation for ball release. As toe off commenced, sagittal plane torque began to increase but remained minimal as the bowler relies on momentum gained during the run-up to terminate foot contact rather than actively pushing off.

Ankle joint moments during front foot contact highlight the largely planar motion of the foot, with the peak moment in the sagittal plane (mean: 3.21 ± 1.71 $Nm{\cdot}Kg^{-1}$) far greater in magnitude compared to those generated in both the frontal (mean: 2.37 ± 1.63 $Nm{\cdot}Kg^{-1}$) and transverse (mean: 0.98 ± 0.36 $Nm{\cdot}Kg^{-1}$) planes. Similar to the back foot, peak joint moments were found to closely coincide with heel contact. The main ankle moment experienced by the front foot during the delivery stride occurred in the sagittal plane, reflective of the functional demands placed upon it. Following heel strike, the sagittal plane moment decreased during foot flat but then rapidly ascended into plantarflexion as the bowler actively pushed off in order to increase the height of ball release. After ball release, ankle joint moments stabilised, reflective of the need for the front foot to provide a base of support during the remainder of the bowling action.

Disparity in ankle joint moments between the back and front foot were established (Table 1). Whilst peak ankle joint moments followed the trend of reported ground kinetics, with the front foot exhibiting greater magnitudes in comparison to the back foot, this trend did not pertain to both average joint moments and average rate of joint loading. Peak moments such as the large peak plantarflexion moment observed with the front foot may be associated with acute injury formation such as that reported by Smith (1999). Whilst reporting of peak values aids in the understanding of acute injuries, both average moments and average rate of joint loading provide greater insight into the overall strain placed on the ankle joint throughout foot contact. Average rate of joint loading in both the sagittal and transverse planes were similar between the front and back foot, however, loading in the frontal plane for the back foot (mean: 1.11 ± 0.82 $Nm{\cdot}Kg^{-1}{\cdot}s^{-1}$) was 246% greater compared to the front foot (mean: 0.45 ± 0.20 $Nm{\cdot}Kg^{-1}{\cdot}s^{-1}$). High frontal plane loading when combined with loading in the other cardinal planes places strain on the supportive structures of the ankle as they must stabilise the ankle from multidirectional forces. Findings from this study would suggest that whilst the front foot is prone to acute injuries, the back foot may be more susceptible to overuse injuries such as lateral ankle instability.

Table 1: Ankle joint kinetics (mean ± SD) during the delivery stride

Joint Kinetics	Back Foot	Front Foot
Peak joint moment ($Nm{\cdot}Kg^{-1}$)		
Plantarflexion/Dorsiflexion	1.70 ± 0.87	3.21 ± 1.71
Varus/Valgus	1.68 ± 1.11	2.37 ± 1.63
Inversion/Eversion	0.96 ± 0.74	0.98 ± 0.36
Average joint moment ($Nm{\cdot}Kg^{-1}$)		
Plantarflexion/Dorsiflexion	0.43 ± 0.29	1.10 ± 0.47
Varus/Valgus	0.55 ± 0.34	0.79 ± 0.54
Inversion/Eversion	0.32 ± 0.22	0.21 ± 0.08
Rate of joint loading ($Nm{\cdot}Kg^{-1}{\cdot}s^{-1}$)		
Plantarflexion/Dorsiflexion	1.64 ± 1.40	2.28 ± 1.05
Varus/Valgus	2.04 ± 1.50	1.72 ± 1.29
Inversion/Eversion	1.11 ± 0.82	0.45 ± 0.20

CONCLUSION: The aim of this study was to quantify ankle joint moments experienced by the front and back foot during the delivery stride to provide greater insight into the aetiology of associated ankle injuries. High peak sagittal moments indicate that the front foot is more prone to acute injuries, whilst the back foot may be more susceptible to overuse injuries due to the multidirectional forces placed upon it throughout foot contact. Findings from this study suggest that rather than utilising kinematic and kinetic data in isolation to investigate pathomechanics of injury, methodology such as inverse dynamics can be successfully applied to provide a greater holistic understanding.

REFERENCES:

Cappozzo, A., Catani, F., Croce, U. D., & Leardini, A. (1995). Position and orientation in space of bones during movement: Anatomical frame definition and determination. *Clinical Biomechanics*, 10, 171-178.

Hurrion, P., Dyson, R., Hale, T. (2000). Simultaneous measurement of back and front foot ground reaction forces during the same delivery stride of the fast-medium bowler. *Journal of Sports Sciences*, 18, 993-997.

Orchard, J., James, T., Alcott, E., Carter, S., & Farhart, P. (2002). Injuries in Australian cricket at first class level 1995/1996 to 2000/2001. *British Journal of Sports Medicine*, *36*, 270-5

Shorter, K., Smith, N., Dyson, R. (2008). Kinetic and kinematic changes associated with altering heel height during cricket medium-fast cricket bowling. Proceedings of International Society for Biomechanics in Sports. p. 279.

Smith, C. (1999). Ankle injuries in fast bowlers: posterior talar impingement syndrome: the South African experience. *5th IOC World Congress on Sport Sciences*, p. 245. Canberra, ACT: Sports Medicine Australia.

Winter, D. (1990). *Biomechanics and motor control of human movement*. John Wiley and Sons, New York, NY.